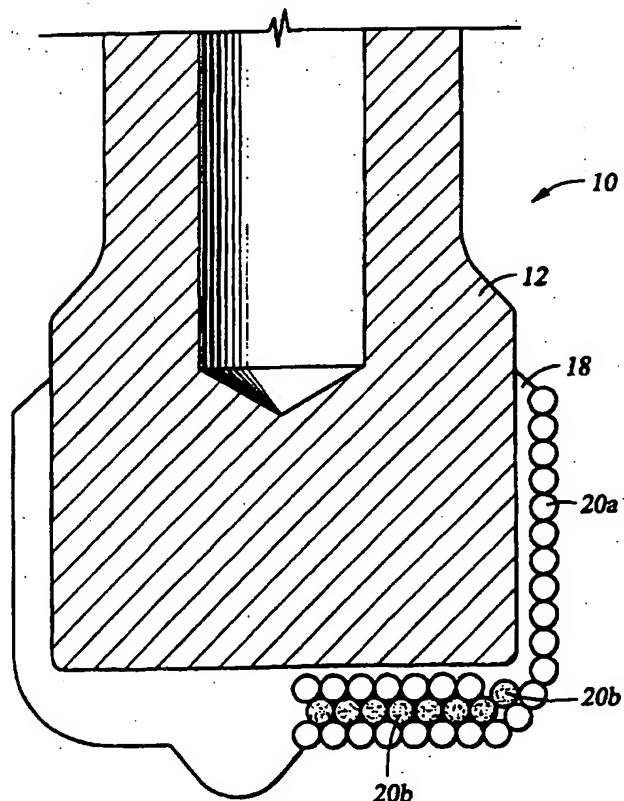




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US97/17170 <b>(22) International Filing Date:</b> 24 September 1997 (24.09.97)  <b>(30) Priority Data:</b> 60/027,386                      27 September 1996 (27.09.96)    US 08/936,056                      23 September 1997 (23.09.97)    US  <b>(71) Applicant:</b> BAKER HUGHES INCORPORATED [US/US]; Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).  <b>(72) Inventors:</b> SCOTT, Danny, Eugene; 3015 Poe, Montgomery, TX 77356 (US). OLDHAM, Jack, Thomas; 15184 Paradise Point Drive, Willis, TX 77378 (US). LYNDE, Gerald, D.; 6418 Brittany Park Lane, Houston, TX 77066 (US). NAZ- ZAL, Greg; 3918 Laurel Rock, Kingwood, TX 77345 (US). SWANSON, Roy, E.; 1803 Hanbury Court, Sugarland, TX 77478 (US). RANDALL, Brad; 11 Moon Beam Court, The Woodlands, TX 77381 (US). ANDERSON, James, W.; 19947 Mountain Dale, Cypress, TX 77433 (US).  <b>(74) Agent:</b> CARSON, Matt, W.; Baker Hughes Incorporated, Intellectual Property Dept., P.O. Box 4740, Houston, TX 77210-4740 (US).		<b>(81) Designated States:</b> AU, CA, GB, NO.  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i>
<b>(54) Title:</b> COMBINATION MILLING TOOL AND DRILL BIT  <b>(57) Abstract</b> <p>A combination metal milling and earth drilling tool (10), for use in performing a single trip kickoff from a casing in a well bore. The combination milling and drilling tool (10) has a first, relatively more durable cutting structure (20a, 22), such as tungsten carbide, and a second, relatively harder cutting structure (20b, 24), such as polycrystalline diamond. The more durable first cutting structure (20a, 22) is better suited for milling metal casing, while the harder second cutting structure (20b, 24) is better suited for drilling through a subterranean formation, especially a rock formation. The first cutting structure (20a, 22) is positioned so that the first cutting structure (20a, 22) will mill through the metal casing while shielding the second cutting structure (20b, 24) from contact with the casing. The first cutting structure (20a, 22) can wear away while milling through the casing. The second cutting structure (20b, 24) can then be used to drill through the rock formation.</p>		



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## TITLE OF THE INVENTION

## Combination Milling Tool and Drill Bit

## BACKGROUND OF THE INVENTION

5       The present invention is in the field of tools used for drilling oil and gas wells. Specifically, this invention applies to the drilling of a new well bore which branches off from an existing well bore which has been drilled and cased.

      It very often occurs that after a well bore has been drilled and the casing installed, a need arises to drill a new well bore off to the side, or at an angle, from the original well  
10   bore. The new well bore may be a lateral bore extending outwardly from the original vertical well bore. The process of starting a new well bore from the existing bore is often called "kicking off" from the original bore. Kicking off from an existing well bore in which metal casing has been installed requires that the casing first be penetrated at the desired depth.

15       Typically, a section mill or window mill is used to penetrate the metal casing, then the window mill and the drill string are withdrawn from the well bore. Following the milling of the window, a drill bit is mounted on the drill string, run back into the well, and used to drill the lateral well bore. Tripping in and out of the well bore delays the drilling process and makes the well more expensive to complete. The reason for using two  
20   different tools in spite of this is that the window mill must penetrate the metal casing, while the drill bit must penetrate the subterranean formation, which often contains highly abrasive constituents.

      Milling of metal requires a cutting structure, such as a cutting insert, which is formed of a material hard enough to cut the metal but durable enough to avoid excessive  
25   breakage or chemical deterioration of the insert. If the insert crumbles or deteriorates excessively, the insert will lose the sharp leading edge which is considered most desirable for the effective milling of metal. Both hardness and durability are important. It has been found that a material such as tungsten carbide is sufficiently hard to mill typical casing steel, while it is structurally durable and chemically resistant to exposure to the casing  
30   steel, allowing the insert to wear away gradually rather than crumbling, maintaining its sharp leading edge.

Drilling through a rock formation requires a cutting structure which is formed of a material as hard as possible, to allow the insert to gouge or scrape chunks out of the rock without excessive wear or abrasion of the insert. This permits the drilling operator to drill greater lengths of bore hole with a single drill bit, limiting the number of trips into and out of the well. It has been found that a material such as polycrystalline diamond is an excellent choice for drilling through a rock formation, because of its extreme hardness and abrasion resistance.

Tungsten carbide is not as good for drilling through a rock formation as polycrystalline diamond, because the diamond is harder and will therefore last longer, limiting the number of trips required. Polycrystalline diamond is not as good for milling through metal casing as tungsten carbide, because the diamond is not as structurally durable, allowing it to crumble more readily and destroy the sharp leading edge. Further, polycrystalline diamond has a tendency to deteriorate through a chemical reaction with the casing steel. There is a chemical reaction between the iron in the casing and the diamond body, which occurs when steel is machined with a diamond insert. As a result of this chemical reaction, the carbon in the diamond turns to graphite, and the cutting edge of the diamond body deteriorates rapidly. This prevents the effective machining of the steel casing with diamond. Therefore, tungsten carbide is the better choice for milling through the metal casing, and polycrystalline diamond is the better choice for drilling through the rock formation.

Unfortunately, use of each type of cutting insert in its best application requires that a first tool be used to kickoff from the original bore, and a second tool be used to drill the new bore, after kickoff. This means that two trips are required for the kickoff and drilling operation. It would be very desirable to be able to perform a single trip kickoff and drilling operation, thereby eliminating at least one trip into and out of the bore hole.

### BRIEF SUMMARY OF THE INVENTION

The present invention is a combination milling and drilling tool for use in performing a single trip kickoff and drilling operation. The tool has a first type of cutting structure suitable for metal milling, for performing the kickoff operation, and a second type of cutting structure suitable for rock drilling, for drilling through the subterranean formation, subsequent to kickoff. The first and second types of cutting structures are

positioned relative to each other on the tool so that only the first type of cutting structure contacts the metal casing during the milling operation, after which the second type of cutting structure is exposed to contact with the subterranean formation during the drilling operation. The first type of cutting structure can be formed of a relatively more durable material than the second type of cutting structure, because it will need to maintain its sharp leading edge during metal milling. The second type of cutting structure can be formed of a relatively harder material than the first type of cutting structure, because it will need to resist wear and abrasion during rock drilling. The first type of cutting structure can be formed of tungsten carbide,  $\text{Al}_2\text{O}_3$ , TiC, TiCN, or TiN, or another material hard enough to mill casing steel but relatively durable and chemically nonreactive with the steel. The second type of cutting structure can be formed of polycrystalline diamond or another material of similar hardness to facilitate drilling through a rock formation.

Two different general schemes can be used to position the first type of cutting structure relative to the second type of cutting structure so as to protect the second type of cutting structure from contact with the steel casing during milling. Each type of positioning scheme can have several different embodiments. The first type of scheme is to use two different types of cutting inserts, with one type being made of a relatively more durable material, such as tungsten carbide, and with the other type being made of a relatively harder material, such as polycrystalline diamond. The more durable inserts are placed on the tool so that they extend farther outwardly than the harder inserts, such as by placing a row of harder inserts behind a row of more durable inserts. The expression "farther outwardly" is used here to mean farther toward the outermost extremity of the tool, in a given direction. It may mean "lowermost" on the lower end of the tool, or "radially outermost" on the sides of the tool. On the bottom end of the tool, for example, a row of the more durable inserts would be placed lowermost, with a row of the harder inserts positioned just above. The size and placement of the more durable inserts are designed to allow these inserts to wear away completely at the approximate time that the casing has been penetrated. This exposes the harder inserts to contact with the rock formation for drilling.

This relative placement of the two types of inserts can be achieved by their relative placement on a given blade of the tool, with appropriate row placement as described

above. Alternatively, the more durable type of insert can be placed on a first blade and the harder type of insert can be placed on a second blade. Then, the two blades can be positioned on the tool so that the first blade extends farther, downwardly or radially outwardly or both, than the second blade.

5       A second type of scheme for relative positioning of the two types of cutting structures involves the use of composite cutting inserts. Each such insert is formed as a composite of several different types of materials, with at least one more durable material being used to shield the less durable but harder material. This can be done in several ways. A cylindrical insert can have a solid inner core of polycrystalline diamond and an  
10       outer layer around its periphery of tungsten carbide. Alternatively, a cylindrical tungsten carbide insert can have a button or pocket of polycrystalline diamond embedded in one face. In yet another alternative, a polycrystalline diamond insert can be coated with one or more durable coatings, such as  $\text{Al}_2\text{O}_3$ , TiC, TiCN, or TiN. The composite inserts are then placed on the blades of the tool. The outer layer or coating of more durable material is  
15       designed to wear away as the milling operation is completed, exposing the inner body of harder material to the rock formation.

The novel features of this invention, as well as the invention itself, will be best understood from the attached drawings, taken along with the following description, in  
20       which similar reference characters refer to similar parts, and in which:

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a section view of one embodiment of the combination milling and drilling tool according to the present invention;

25       Figure 2 is a side elevation view of the tool shown in Figure 1;

Figure 3 is a section view of a second embodiment of the tool according to the present invention;

Figure 4 is a side elevation view of the tool shown in Figure 3;

Figure 5 is a plan view of one embodiment of a composite cutting insert for use in  
30       a tool according to the present invention;

Figure 6 is a section view of the insert shown in Figure 5;

Figure 7 is a plan view of a second embodiment of a composite cutting insert for use in a tool according to the present invention;

Figure 8 is a section view of the insert shown in Figure 7;

Figure 9 is a plan view of a third embodiment of a composite cutting insert for use  
5 in a tool according to the present invention;

Figure 10 is a section view of the insert shown in Figure 9;

Figure 11 is a section view of a fourth embodiment of a composite cutting insert for use in a tool according to the present invention; and

Figure 12 is an enlarged section view of a portion of the insert shown in Figure 11.

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### DETAILED DESCRIPTION OF THE INVENTION

As shown in Figure 1, the tool 10 of the present invention has a generally cylindrical body 12, with a lower end 14 and a periphery 16. One or more blades 18 are mounted to the lower end 14 and the periphery 16 of the tool body 12. The configuration  
15 of the tool 10 is not limited to the tool shown here; other configurations could be adapted as well.

One or more cutting structures in the form of cutting inserts 20 are affixed to a plurality of the blades 18, such as by brazing or any other suitable method. The cutting inserts 20 can be of various different types, as will be explained, depending upon what  
20 type of positioning scheme is utilized to cause a relatively more durable cutting structure to contact the casing, and to cause a relatively harder cutting structure to contact the rock formation. In one type of positioning scheme, as shown in Figure 2, a first plurality of the cutting inserts 20a can be formed of a relatively more durable material such as tungsten carbide, and a second plurality of the cutting inserts 20b can be formed of a relatively  
25 harder material such as polycrystalline diamond. The first plurality of tungsten carbide inserts 20a are placed on a first blade 18a, while the second plurality of polycrystalline diamond inserts 20b are placed on a second blade 18b. The lowermost extremity 19a of the first blade 18a extends below the lowermost extremity 19b of the second blade 18b. Similarly, the outer periphery of the first blade 18a extends radially outwardly farther than  
30 the outer periphery of the second blade 18b. When the tool 10 of this embodiment is rotated within a metal casing, the tungsten carbide inserts 20a will contact the casing in a milling operation, while the diamond inserts 20b will not contact the casing. The tool

also could be built to allow the second blade 18b to have slight or incidental contact with the casing, without appreciable force being applied, thereby preventing cutting contact between the diamond inserts 20b and the casing. As will be shown in later embodiments, the tungsten carbide also could be formed actually around the diamond to physically shield the diamond from contact with the casing. All of these approaches fall within the spirit of the invention. In the embodiment shown, the first blade 18a is designed to extend farther outwardly than the second blade 18b to the appropriate extent to allow the first blade 18a to penetrate the metal casing at about the time it has worn away sufficiently that the second blade 18b contacts the surrounding formation.

Figures 3 and 4 show another embodiment of the tool 10 which employs this same type of positioning scheme, but in a different way. In this embodiment, each blade 18 carries a first, outermost, row of tungsten carbide inserts 20a, and a second, inner row of diamond inserts 20b. A third row of inserts can also be added as shown. This embodiment of this type of positioning scheme can also utilize other placement patterns, incorporating for instance gage cutting inserts, or incorporating a wider spacing of inserts. The key element is that the tungsten carbide inserts 20a are positioned so as to mill through the metal casing while protecting the diamond inserts 20b from contact with the casing. At approximately the time that the casing has been penetrated, the row of tungsten carbide inserts are designed to wear away sufficiently to allow the diamond inserts 20b to contact the rock formation. In this embodiment, each blade 18 extends downwardly and outwardly to the same extent as the other blades 18, since each blade 18 has an outermost row of tungsten carbide inserts 20a and an inner row of diamond inserts 20b.

In a second type of positioning scheme, at least some of the cutting inserts 20 can be composite inserts which are identical to each other, with each blade 18 having the inserts 20 mounted thereon, as shown in Figure 1. However, in this second type of positioning scheme, the relative positioning of the two types of cutting structures is accomplished by using composite inserts such as the embodiment shown in Figures 5 and 6. A cutting insert 20c is formed as a composite of two materials, with one material being relatively harder, and the other material being relatively more durable. A substantially cylindrical inner body 24 of polycrystalline diamond has at least one exposed end 21, with an outer layer 22 of tungsten carbide formed around its periphery 23. The exposed end of



the outer layer 22 has a chamfered edge 26 and a chip breaking annular groove 28. This edge 26 and the chip breaking groove 28 contact the metal casing during the milling operation, to cut short, thick chips from the casing. This allows the metal chips to be removed from the well bore by circulation of the drilling fluid without birdnesting and clogging the hole. At approximately the time that the metal casing has been penetrated,  
5 the outer layer 22 is designed to wear away sufficiently to allow the inner body 24 to contact the rock formation for drilling purposes.

A second embodiment of a composite insert 20d which can be used in this second type of positioning scheme is shown in Figures 7 and 8. Here, an outer tungsten carbide  
10 layer 22 surrounds the periphery 23 of the inner diamond body 24 as discussed before. In this embodiment, however, the inner body 24 is formed with a chamfered edge 25 around its exposed upper end 21, giving the diamond inner 24 body increased durability as penetration of the metal casing is completed and the drilling of the rock formation begins. The outer layer 22 has a chamfered edge 26 and a chip breaking groove 28 as before.

15 A third embodiment of a composite insert 20e which can be used in this second type of positioning scheme is shown in Figures 9 and 10. In this embodiment, a cup shaped outer tungsten carbide layer 22 is formed around the periphery and one end of a polycrystalline diamond button shaped inner body 24. Here again, the outer layer 22 has a chamfered edge 26 and a chip breaking groove 28. Use of the cup shaped outer layer 22  
20 provides a tungsten carbide lower end 29 on the insert 20e, which can facilitate brazing the insert 20e to a blade 18.

A fourth embodiment of a composite insert 20f which can be used in this second type of positioning scheme is shown in Figures 11 and 12. In this embodiment, a polycrystalline diamond body 24 is mounted to a tungsten carbide substrate 22, with a  
25 thin, durable coating 30 deposited over the diamond body 24. The primary purpose of using the coating embodiment is to place a chemically resistant coating over the diamond body. This prevents the normal chemical reaction between the iron in the casing and the diamond body, which occurs when steel is machined with a diamond insert. As a result of this chemical reaction, the carbon in the diamond turns to graphite, and the cutting edge of  
30 the diamond body deteriorates rapidly. This prevents the effective machining of the steel casing with diamond. The coating 30 can be deposited in several layers to facilitate adherence to the diamond body 24. The process of depositing these layers 30 can be

physical vapor deposition (PVD) or chemical vapor deposition (CVD), with PVD being preferred. Or, a tungsten carbide coating can be applied in a high temperature, high pressure (HTHP) apparatus. Examples of materials which could be used in the PVD or CVD processes are  $\text{Al}_2\text{O}_3$ , TiC, TiCN, or TiN. Combinations of the PVD, CVD, and  
5 HTHP processes could also be used, to create a "sandwich" of durable, chemical resistant coatings. The coating protects the diamond during the milling process, but it wears away rapidly upon exposure to the rock formation.

While the particular invention as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages hereinbefore stated, it is to  
10 be understood that this disclosure is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended other than as described in the appended claims.

## CLAIMS

We claim:

- 1           1.     A combination milling and drilling tool for kicking off from an existing  
2 casing in a well bore, comprising:  
3           a tool body mountable on a drill string suspended within a casing in a well bore;  
4           a first cutting structure mounted to said tool body, said first cutting structure being  
5                 a metal milling structure constructed of a material having properties of  
6                 shape, hardness, and durability designed for milling through a metal  
7                 casing; and  
8           a second cutting structure mounted to said tool body, said second cutting structure  
9                 being a formation drilling structure constructed of a material having  
10                properties of shape, hardness, and durability designed for drilling through a  
11                subterranean formation;  
12          wherein, said second cutting structure is situated relative to said first cutting  
13          structure so as to minimize the occurrence of cutting contact between said  
14          second cutting structure and the metal casing, and so as to cause said  
15          second cutting structure to contact the subterranean formation after said  
16          first cutting structure has penetrated the metal casing.

1           2.     A combination milling and drilling tool as recited in claim 1, wherein:  
2           said first cutting structure comprises a first insert having a first level of hardness  
3           and a first level of durability;  
4           said second cutting structure comprises a second insert having a second level of  
5           hardness and a second level of durability;  
6           said first level of durability is greater than said second level of durability;  
7           said second level of hardness is greater than said first level of hardness;  
8           said first insert is positioned on said tool body so as to come into contact with the  
9           metal casing before said second insert contacts the metal casing; and  
10          said second insert is positioned on said tool body so as to come into cutting  
11          contact with the subterranean formation only after said first insert wears  
12          away during milling of the casing.

1           3.     A combination milling and drilling tool as recited in claim 2, wherein:  
2           said first insert is positioned on an outer extremity of said tool body so as to come  
3           into first contact with a metal casing; and  
4           said second insert is positioned inwardly on said tool body, relative to said first  
5           insert, so as to minimize contact with the metal casing.

1           4.     A combination milling and drilling tool as recited in claim 3, wherein said  
2           first and second inserts are positioned on the same blade on said tool body, with said first  
3           insert being positioned outwardly relative to said second insert.

1           5.     A combination milling and drilling tool as recited in claim 3, wherein:  
2           said first insert is positioned on a first blade on said tool body;  
3           said second insert is positioned on a second blade on said tool body; and  
4           said first blade extends outwardly farther than said second blade.

1           6.     A combination milling and drilling tool as recited in claim 3, wherein said  
2     first insert comprises a tungsten carbide insert.

1           7.     A combination milling and drilling tool as recited in claim 3, wherein said  
2     second insert comprises a polycrystalline diamond insert.

1           8.     A combination milling and drilling tool as recited in claim 1, wherein:  
2     said first cutting structure and said second cutting structure are combined in a  
3     cutting insert;  
4     said first cutting structure comprises an outer portion of said cutting insert, said  
5     outer portion having a first level of hardness and a first level of durability;  
6     said second cutting structure comprises an inner portion of said cutting insert, said  
7     inner portion having a second level of hardness and a second level of  
8     durability;  
9     said first level of durability is greater than said second level of durability; and  
10    said second level of hardness is greater than said first level of hardness.

1           9.     A combination milling and drilling tool as recited in claim 8, wherein:  
2     said inner portion of said cutting insert comprises a solid body having a front face  
3     for cutting the subterranean formation;  
4     said outer portion of said cutting insert comprises a layer surrounding a periphery  
5     of said solid body, shielding said solid body from contact with the metal  
6     casing, while leaving said front face exposed; and  
7     said layer wears away during milling of the casing, to leave said solid body  
8     exposed to contact with the subterranean formation.

1           10.    A combination milling and drilling tool as recited in claim 9, wherein said  
2   outer portion comprises a tungsten carbide layer.

1           11.    A combination milling and drilling tool as recited in claim 9, wherein said  
2   inner portion comprises a polycrystalline diamond body.

1           12.    A combination milling and drilling tool as recited in claim 8, wherein:  
2        said inner portion of said cutting insert comprises a solid body having a front face  
3               for cutting the subterranean formation;  
4        said outer portion of said cutting insert comprises a coating deposited over said  
5               front face of said solid body, shielding said solid body from contact with  
6               the metal casing; and  
7        said coating is adapted to wear after milling of the casing, to leave said solid body  
8               exposed to contact with the subterranean formation.

1           13.    A combination milling and drilling tool as recited in claim 12, wherein  
2   said outer portion comprises a coating adapted for metal cutting.

1           14.    A combination milling and drilling tool as recited in claim 12, wherein  
2   said inner portion comprises a polycrystalline diamond body.

1           15.    A combination milling and drilling tool as recited in claim 1, wherein said  
2   second cutting structure is situated relative to said first cutting structure so as to actually  
3   prevent cutting contact between said second cutting structure and the metal casing.

1           16.    A method for performing a single trip kickoff from a casing in a well bore,  
2    said method comprising:  
3           providing a combination milling and drilling tool mounted on a drill string  
4           suspended within a casing in a well bore, said tool having a first cutting  
5           structure and a second cutting structure, said first cutting structure being  
6           comparatively more durable than said second cutting structure, said second  
7           cutting structure being comparatively harder than said first cutting  
8           structure and positioned inwardly on said tool relative to said first cutting  
9           structure;  
10          rotating said combination tool within the casing to cause said first cutting structure  
11          to mill through the casing, while said second cutting structure is shielded  
12          from contact with the casing;  
13          exposing said second cutting structure to a subterranean formation outside the  
14          casing; and  
15          rotating said combination tool to cause said second cutting structure to drill  
16          through the subterranean formation.

1           17.    A method as recited in claim 16, wherein:  
2           said first and second cutting structures are combined into a composite cutting  
3           insert having a relatively more durable outer portion and a relatively harder  
4           inner portion; and  
5           said inner portion is exposed to the subterranean formation by wearing of said  
6           outer portion after milling of the casing.

1           18.    A method as recited in claim 16, wherein:  
2           said first cutting structure comprises a first cutting insert having a relatively more  
3           durable composition;  
4           said second cutting structure comprises a second cutting insert having a relatively  
5           harder composition; and  
6           said second cutting insert is exposed to the subterranean formation by wearing  
7           away of said first cutting insert during milling of the casing.

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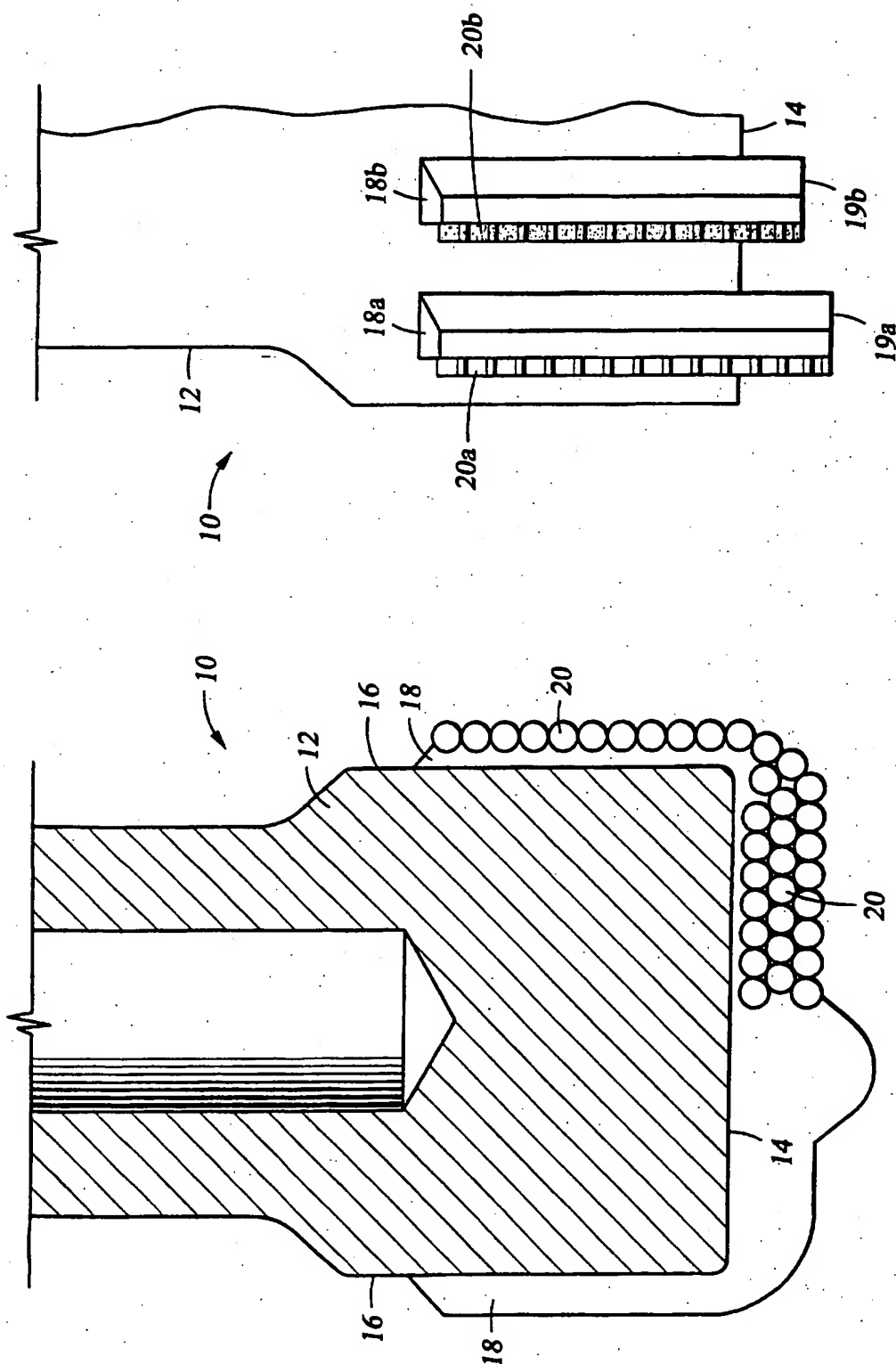


Fig. 1

Fig. 2



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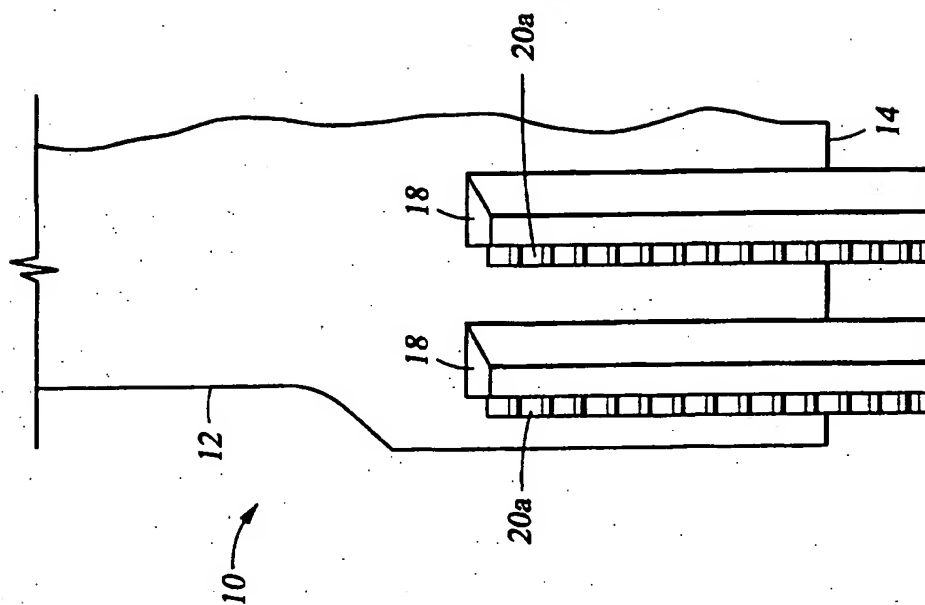


Fig. 4

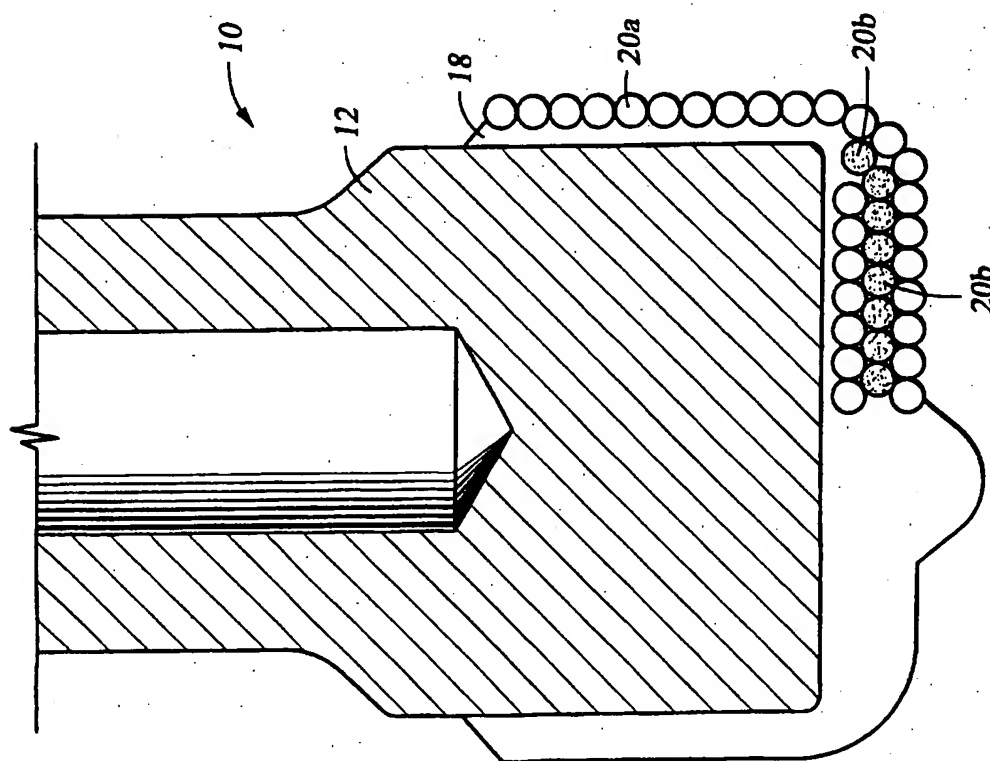


Fig. 3

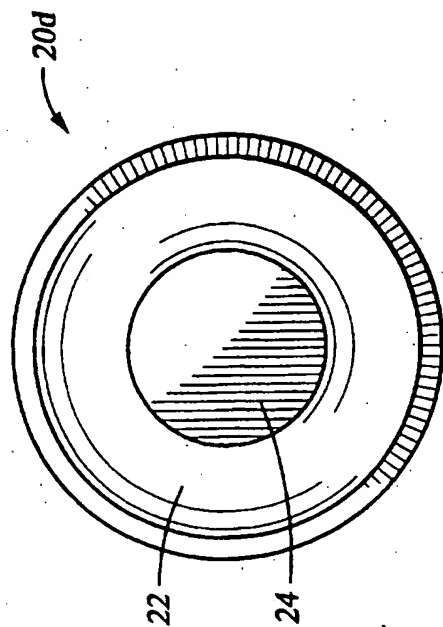


Fig. 7

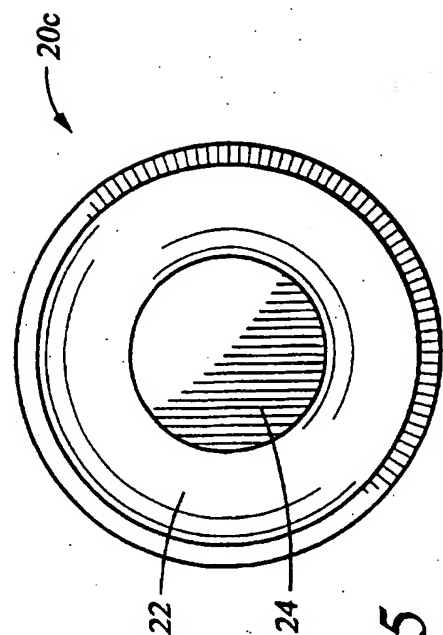


Fig. 5

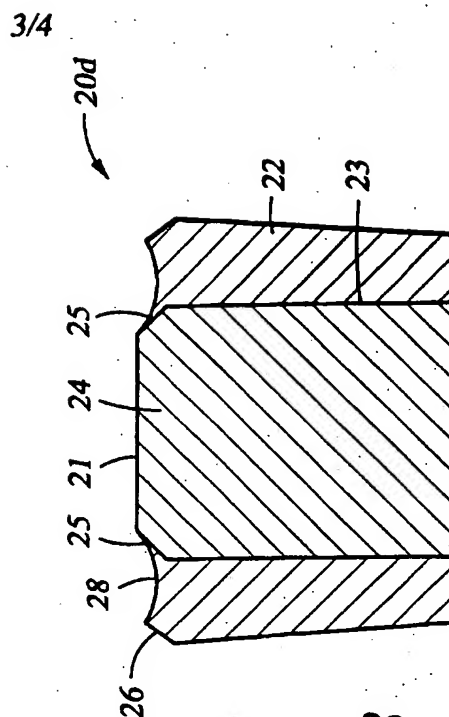


Fig. 8

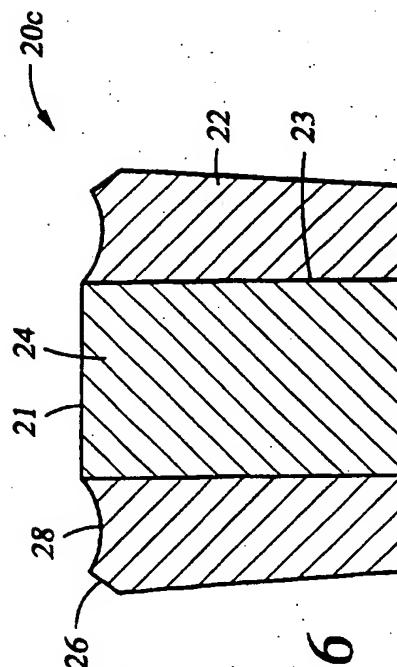


Fig. 6

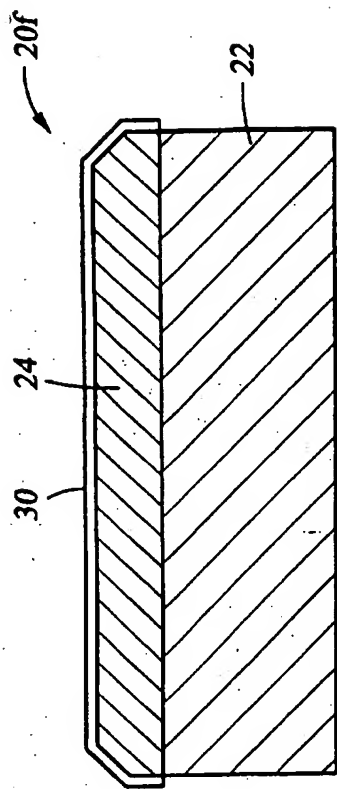


Fig. 11

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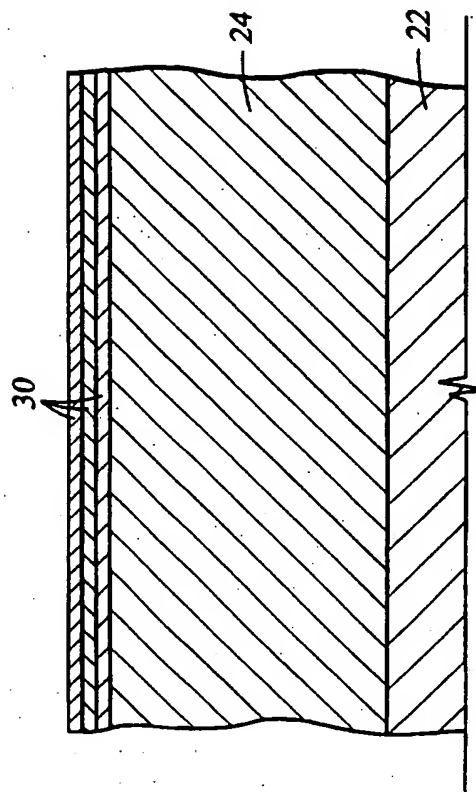


Fig. 12

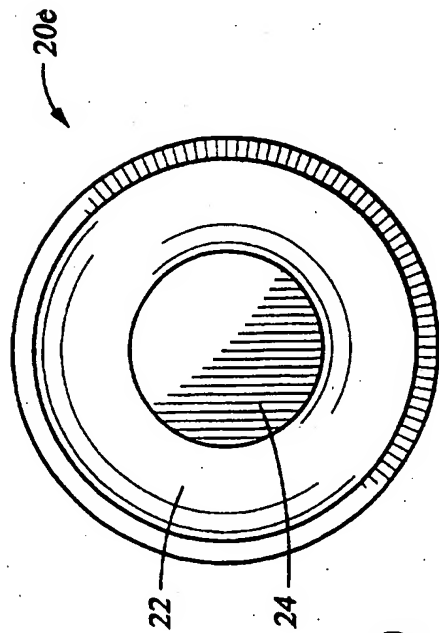


Fig. 9

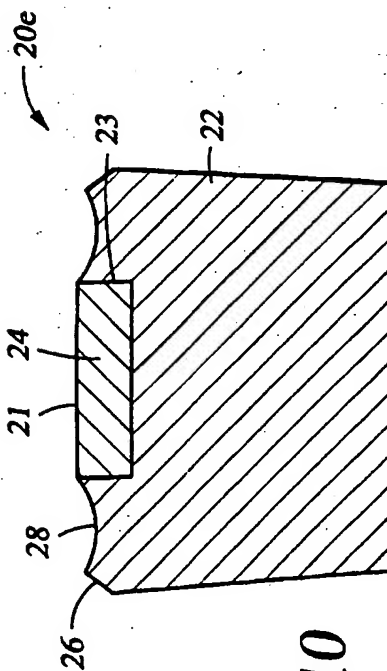


Fig. 10

## INTERNATIONAL SEARCH REPORT

 International application No.  
 PCT/US97/17170

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(6) : E21B 7/08, 10/46, 29/06, US CL : 175/61, 431; 166/298, 55.1 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) U.S. : 175/61, 80, 81, 82, 307, 374, 379, 425, 426, 428, 431, 434; 166/298, 55.1 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,135,061 A (NEWTON, JR.) 4 August 1992 (04/08/92), see figures 1-8 and column 4, lines 31-37.	1,8,12-15
X	US 5,025,874 A (BARR et al) 25 June 1991, see figures 6-11, 15-17 and column 3, lines 30-43.	1,8,12-15
X	GB 2,086,451 A (JURGENSE) 12 May 1982 (12/05/82), see figures 6-7 and page 3, lines 18-24.	1-3,5,7,15
X	US 5,248,006 A (SCOTT et al) 28 September 1993 (28/09/93), see figures 1-4 and column 3, line 54 through column 4, line 7.	1,8-11,15
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
*A*	document defining the general state of the art which is not considered to be of particular relevance	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*E*	earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*L*	document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*O*	document referring to an oral disclosure, use, exhibition or other means	*A* document member of the same patent family
*P*	document published prior to the international filing date but later than the priority date claimed	
Date of the actual completion of the international search 07 JANUARY 1998		Date of mailing of the international search report 06 MAR 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer HOANG DANG Telephone No. (703) 308-2168

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/17170

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,255,165 A (DENNIS et al) 10 March 1981 (10/03/81), see figures 2A-4B see column 4, lines 3-21, column 5, lines 3-22.	1,8-1516
A	US 5,027,912 A (JUERGENS) 02 July 1991 (02/07/91), see the entire patent.	1,8-11,15
A	US 5,423,387 A (LYNDE) 13 June 1995 (13/06/95), see column 4, lines 55-62.	16-18
A	US 5,531,281 A (MURDOCK) 02 July 1996 (02/07/96), see the entire patent.	1-15

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/17170

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/17170

### BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains claims directed to more than one species of the generic invention. These species are deemed to lack Unity of Invention because they are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for more than one species to be searched, the appropriate additional search fees must be paid. The species are as follows: the species of Figure 2; the species of Figures 3-4; and the species of Figures 5-12.

The claims are deemed to correspond to the species listed above in the following manner:

Group I: Figures 3-4: claim 2-4, 6, 7, 15 and 18

Group II: Figure 2: claim 5

Group III: Figures 5-12: claims 8-14 and 17

The following claims are generic: 1 and 16

The species listed above do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons:

The special technical feature of the species of Figure 2 is the mounting of first and second cutting structures or inserts on different blades, one blade extending deeper into the formation to be cut than the other blade.

The special technical feature of the species of Figures 3-4 is the mounting of separate first and second cutting structures or inserts on the same blade, one type of cutting structure positioned above the other type of cutting structure on the same blade.

The special technical feature of the species of Figures 5-12 is the use of a single cutting insert that includes both first and second cutting structures.